ORIGINAL

BECKER & MADISON
CHARTERED
1915 EYE STREET, N.W.
EIGHTH FLOOR
WASHINGTON, D.C. 20006
(202) 833-4422
TELECOPIER
(202) 296-7458

RICHARD S. BECKER
PAUL G. MADISON

OF COUNSEL
JAMES S. FINERFROCK

CONSULTING ENGINEER
SIAMAK HARANDI

DOCKET FILE COPY ORIGINAL

RECEIVED

MAY 28 1993

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

May 28, 1993

Donna R. Searcy, Secretary
Federal Communications Commission
Washington, DC 20554

Re: PR Docket No. 92-235
In the matter of
Replacement of Part 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them

Dear Ms. Searcy:

Transmitted herewith on behalf of The Academy of Model Aeronautics is an original and four copies of its "Supplement to Comments of The Academy of Model Aeronautics" filed with respect to the above-referenced proceeding.

Should any questions arise with respect to this matter, please communicate directly with this office.

Respectfully submitted,

Paul Madison

Paul G. Madison
Attorney for The Academy of Model Aeronautics

No. of Copies rec'd 0+4
List A B C D E

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

DOCKET FILE COPY ORIGINAL

In the matter of	)	
	)	
Replacement of Part 90 by Part 88 to	)	**PR Docket No. 92-235**
Revise the Private Land Mobile Radio	)	
Services and Modify the Policies	)	
Governing Them	)	

To: The Commission

SUPPLEMENT TO
COMMENTS OF THE ACADEMY OF MODEL AERONAUTICS

Respectfully submitted,

THE ACADEMY OF MODEL AERONAUTICS, INC.

Richard S. Becker
James S. Finerfrock
Paul G. Madison
Becker & Madison, Chartered
1915 Eye Street, Northwest
Eighth Floor
Washington, DC 20006
(202) 833-4422

Its Attorneys

Date: May 28, 1993

Table Of Contents

Summary

The Academy of Model Aeronautics, Inc. ("Academy"), submits this Supplement to Comments filed by the Academy in the above-captioned proceeding on March 10, 1993. In this Supplement, the Academy provides to the Commission specific, empirical data demonstrating that the Commission's proposal to allocate 200 narrowband channels in the 72-76 MHz band for low power mobile use in the General Category Pool will cause substantial harmful electrical interference to operation of model aircraft and model surface craft devices using 72 and 75 MHz frequencies allocated in the Radio Control ("R/C") Radio Service exclusively for this purpose pursuant to Part 95, Subparts C and E of the Commission's Rules.

The Academy's primary concern is with the new Section 88.907(d). Section 88.907(d) proposes splitting of 72-76 MHz channels to establish 200 72-76 MHz frequencies for low power mobile use in the General Category Pool. As such, instead of being 10 kHz away from the R/C frequencies, as in Part 90, many of these new land mobile frequencies created by the proposed Section 88.907(d) would only be 2.5 kHz removed from the R/C frequencies. As demonstrated herein, the resulting interference will make loss of control of model craft a highly likely occurrence.

In the Academy's Technical Report, attached hereto, the Academy conclusively demonstrates that low power land mobile operation on those 72-76 MHz channels specified in proposed Section 88.907(d) that are separated on one or both sides by 2.5 kHz from R/C channels allocated pursuant to Part 95 of the Commission's Rules will cause substantial harmful interference to remote control operation of models on R/C frequencies. In other words, without modification, radio operation pursuant to the presently proposed Section 88.907(d), will cause the in-flight loss of control of

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the matter of	)	
	)	
Replacement of Part 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them	))))	**PR Docket No. 92-235**

To: The Commission

SUPPLEMENT TO
COMMENTS OF THE ACADEMY OF MODEL AERONAUTICS

The Academy of Model Aeronautics, Inc. ("Academy"), by its attorneys and pursuant to Section 1.415 of the Commission's Rules, hereby submits this Supplement to Comments ("Comments") filed by the Academy in the above-captioned proceeding on March 10, 1993. In its Comments, the Academy demonstrated that the Commission's proposals for the 72-76 MHz frequency band will have a disastrous effect on an industry with annual sales in excess of $1 billion as well as on an estimated one million Radio Control model enthusiasts. In this Supplement, the Academy provides to the Commission specific, empirical data demonstrating that the Commission's proposal to allocate 200 narrowband channels in the 72-76 MHz band for low power mobile use in the General Category Pool will cause substantial harmful electrical interference to operation of model aircraft and model surface craft devices using 72 and 75 MHz frequencies allocated in the Radio Control ("R/C") Radio Service exclusively for this purpose pursuant to Part 95, Subparts C and E of the Commission's Rules.

Introduction

1. In its Comments, the Academy set forth in detail its interest in the above-captioned proceeding and the vital importance of reliable, interference-free operation on R/C frequencies for remote control of models. There are currently three groups of R/C frequencies allocated pursuant to Part 95 of the Commission's Rules: 6 frequencies at 27 MHz in between Citizens Band frequencies that may be used to control any type of model;[1] 50 frequencies at 72 MHz that may only be used for the control of model aircraft and rockets; and 30 frequencies at 75 MHz that may only be used to control model surface craft, such as boats and 4-wheel vehicles. Comments, p.6-7. At present, Section 90.257 governs land mobile operations in the 72-76 MHz band. Section 90.257(a)(1) sets forth frequencies used for fixed operations.[2] Section 90.257(b)(1) makes the same frequencies available for low power mobile use. Section 90.257(c) cross-references the existence of the R/C channels and their use for remote control of models. All 72-76 MHz channels now allocated pursuant to Section 90.257 are separated by 10 kHz from R/C channels.

2. In its Comments, the Academy pointed out that proposed fixed operations at 72-76 MHz (new Section 88.1189) and proposed radio call box operations at 72-76 MHz (new Section 88.1263) are

[1]As noted in the Comments, operation of model aircraft in the 27 MHz band is not recommended by the Academy because of potential interference from adjacent Citizens Band operations.

[2]Pursuant to Section 90.241(a), these frequencies can also be used for radio call box operations in the Local Government Radio Service.

not a concern to the Academy because those frequencies are the same as in existing Section 90.257(a)(1) -- i.e., 10 kHz separated from R/C frequencies. Comments at 8-9. The R/C community has successfully coexisted with these fixed stations by using appropriate operating procedures and narrowband R/C equipment. Id. at 9.

3. The problem, however, lies in new Section 88.907(d), which proposes splitting of 72-76 MHz channels to establish 200 72-76 MHz frequencies for low power mobile use in the General Category Pool. Instead of being 10 kHz away from the R/C frequencies, many of these new land mobile frequencies would only be 2.5 kHz removed from the R/C frequencies.[3] The Academy demonstrated that these new land mobile frequencies will pose a serious interference threat to remote control of models on 72-76 MHz R/C channels allocated pursuant to Part 95 of the Commission's Rules.[4] Id. at 9-10, 15-17. The Academy observed that the proposed narrowband 72-76 MHz low power mobile frequencies can be used for Public Safety, Non-

---

[3]Specifically, twenty of the 72 MHz R/C channels would be bracketed on both sides by land mobile channels separated by only 2.5 kHz. Six 72 MHz and five 75 MHz R/C channels would be bracketed on the positive side by land mobile channels separated by 2.5 kHz. Five 72 MHz and five 75 MHz R/C channels would be bracketed on the negative side by land mobile channels separated by 2.5 kHz. In sum, 31 of the 50 72 MHz R/C channels (62%) and 10 of the 30 75 MHz R/C channels (33.33%) would be bracketed on one or both sides by a land mobile channel separated by only 2.5 kHz.

[4]The Academy observed that this interference was particularly likely in view of the fact that the proposed frequency stability for low power mobile operation at 72-76 MHz is 50 parts per million pursuant to proposed Section 88.425(a), Table C-2. This frequency stability limit permits the signal to actually take up 3.6 kHz -- enough to be exactly on the R/C frequency only 2.5 kHz away. Id. at 9.

Commercial and Specialized Mobile Radio (i.e., commercial, for-profit service) use and can provide either data or voice communications. Id. at 10. As such, land mobile use of the proposed narrowband 72-76 MHz channels near urban flying sites and public recreational areas is not only permitted, but is also likely. Id. The Academy demonstrated conclusively that the resulting interference will make loss of control of a model craft a highly likely occurrence ultimately causing extensive damage to the industry and creating a severe threat to public safety. Id. at 10-15.

4. Based on these facts, in its Comments, the Academy requested that the Commission revise its proposed Part 88 to: (1) include in the new Part 88 a cross-reference to R/C operations under Part 95 similar to that currently embodied in Section 90.257(c); and (2) exempt the channels used in the R/C service from the proposed land mobile channel-splitting scheme by maintaining 10 kHz separation from land mobile frequencies as currently set forth in the Commission's Rules. It must be emphasized that even if the Commission adopts the Academy's recommendation, proposed Section 88.907(d) will still permit low power, General Category Pool land mobile operation on 659 frequencies. As currently proposed, Section 88.907(d) authorizes 779 low power land mobile frequencies [8 25-50 MHz channels; 200 72-76 MHz channels; 28 150-174 MHz channels; 5 220-221 MHz channels; and 538 450-470 MHz channels]. Therefore, in order to satisfy the Academy's interference concerns by maintaining 10 kHz separation from existing R/C channels, the

Commission would only need to delete 120 72 and 75 MHz channels from Section 88.907(d) [72.0125 through 72.6075 MHz and 75.4325 through 75.6075 MHz]. The Commission could still proceed with allocation of 80 of the 72-76 MHz narrowband channels presently proposed [74.6025 through 75.3975 MHz], as well as the 8 25-50 MHz channels, the 28 150-174 MHz channels, the 5 220-221 MHz channels and the 538 450-470 MHz channels. In other words, the Commission could still proceed with allocation of **659** frequencies constituting **84.59 %** of the number of frequencies originally proposed for low power land mobile use.

The Technical Report

5. Pursuant to the Commission's invitation and authorization, the Academy conducted extensive testing to provide empirical data as to whether land mobile operation on 72-76 MHz frequencies less than 10 kHz away from R/C channels will result in harmful electrical interference to R/C frequencies used for remote control of models.[5] As demonstrated herein, the Academy's tests demonstrated conclusively that the land mobile operations as proposed in Section 88.907(d) will cause substantial harmful electrical interference to R/C operations pursuant to Part 95 of the Commission's Rules. Specifically, attached hereto as Exhibit 1 is a Technical Report by the Academy entitled, "Experimental Evaluation of 72 MHz Land Mobile Operation on Radio Control Model Aircraft." The Technical Report was prepared by Messrs. William

[5]The Commission invited and authorized the Academy to conduct this testing during a March 11, 1993, meeting requested by Mr. Ralph Haller, Chief of the Commission's Private Radio Bureau.

Hershberger, George Steiner and H. Warren Plohr. The Technical Report documents the results of extensive testing conducted on behalf of the Academy from April 19 through April 22, 1993, at the Academy's National Model Airport at Muncie, Indiana. The Technical Report provides conclusive empirical data confirming that low power mobile operation on frequencies separated by less than 10 kHz from R/C channels allocated pursuant to Part 95 of the Commission's

Electronic Engineers ("IEEE"). He also holds a radiotelephone license (PG-4-6171), was granted amateur radio license W8RAY in 1937, and currently holds an advanced amateur license, K4DUL.

George Steiner has been a member of the Academy for 9 years and is a member of the Academy's Frequency Committee. Mr. Steiner was employed by the Pacific Gas and Electric Company for 34 years prior to his retirement in 1982. In that capacity, Mr. Steiner gained extensive knowledge in the installation of microwave systems, telephone communication dial design and installation, power control supervisories, powerline carriers, computer control for sub-stations and, in the last 10 years prior to retirement, construction of two-way mobile communications systems that involved over 1,000 radios. Mr. Steiner is a member of the IEEE and has held an FCC General Radiotelephone license for over 35 years (PG-12-24152). Since retirement, Mr. Steiner has established GSP Products, an electronic manufacturing business specializing in alarm systems for power line carrier control and the design and repair of radio control systems, including a unique procedure to evaluate radio controlled systems in a lab environment for FCC requirements.

H. Warren Plohr has been a member of the Academy since 1936 and a member of the Academy's Frequency Committee for 10 years. Mr. Plohr graduated with a B.S. degree in Engineering from the Carnegie Institute of Technology and an M.S. degree in Engineering from the Case Institute of Technology. Mr. Plohr's career spanned 32 years at NACA, NASA, and as a Research Scientist at the Lewis Research Center in Cleveland, Ohio. Mr. Plohr retired as a member of the Lewis Senior Research Staff. Mr. Plohr has also been a 40 year member of the Amateur Radio Service, holding Amateur Extra Class license, W8IAH.

7. The tests described in the Technical Report analyzed interference signal levels generated by 72 MHz low power land mobile transmissions as measured aboard a radio control model aircraft. A one watt mobile transmitter was operated at distances of 1 to 2.5 miles from the model airport and the land mobile frequencies were offset from the R/C frequency by 2.5, 5 and 7.5 kHz. A radio control model aircraft was outfitted with instrumentation that monitored and recorded the interference

encountered from the mobile's transmissions. The radio control

Supplement:

- Interference was encountered at each mobile transmitter location. Specifically, varying degrees of interference were measured whether the mobile transmitter was 1, 1.5 or 2.5 miles from the flight line.[9]

- The most harmful interference was recorded when the mobile unit operated on a frequency 2.5 kHz separated from the R/C channel. This conclusively confirms the Academy's position that land mobile operations on the 120 72-76 MHz channels in proposed Section 88.907(d) that are separated by 2.5 kHz from R/C channels will cause significant harmful interference that will seriously obstruct radio control of model aircraft pursuant to Part 95 of the Commission's Rules and endanger modelers and the public alike. By maintaining the existing 10 kHz separation between 72-76 MHz land mobile operations and R/C channels the Commission can avoid the interference that has now been proven with 2.5 and 5 kHz separation.[10]

- Although geographic separation can be used to avoid adjacent channel interference in some cases, in the instant case, R/C operations present unique and unusual problems that render elimination of interference via geographic separation impossible. Specifically, model aircraft fly above ground level where they are susceptible to an interfering transmitter located a great distance away. Even if this interference is extremely brief in duration, it can result in loss of control and crash of the model aircraft.

- The telemetered data indicated that the timing of the observed interference during the flight was not predictable. Although some flights showed the expected increase in interference when the aircraft was flown away from the flight line and close to the mobile transmitter, other flights showed an increase in interference only when the aircraft was close to the model airport. This evidence highlights the fact that the RF link between an R/C handheld transmitter and an airborne receiver is

---

[9]See Technical Report at 5 for explanation of the varying levels of interference experienced.

[10]As noted in the Technical Report at 6, no interference was observed during the 2 tests with a 7.5 kHz offset. However, the small number of test flights with a 7.5 kHz offset does not justify a conclusion that no interference could be expected under all flying conditions. Id.

subject to many variables, including how the pilot moves the R/C transmitter during flight and the changing position of the aircraft's trailing wire antenna as the model aircraft maneuvers. As a result of these variables: (1) the presence of even a weak interfering signal can readily capture the aircraft's receiver; (2) the stronger the interfering signal, the longer the loss of control; and (3) even a momentary loss in control can cause a response in the aircraft, ranging from an easily controlled wiggle to a complete loss of control and either break up of the model in flight or crash.

Conclusion

9. The results of the testing set forth in the Academy's Technical Report demonstrate conclusively that proposed low power land mobile operation on those 72-76 MHz channels specified in proposed Section 88.907(d) that are separated on one or both sides by 2.5 kHz from R/C channels allocated pursuant to Part 95 of the Commission's Rules will cause substantial harmful interference to remote control operation of models on R/C frequencies. In its Comments, the Academy specifically documented the extensive risk of damage to property and public safety that such interference will engender. The Commission must respond to this vital public interest issue by modifying its proposed Part 88 to: (1) include in Part 88 a cross-reference to R/C operations under Part 95 similar to that currently embodied in Section 90.257(c); and (2) exempt the channels used in the R/C service from the land mobile

channel-splitting scheme by maintaining the 10 kHz separation from land mobile frequencies as currently embodied in the Commission's Rules.

Respectfully submitted,

THE ACADEMY OF MODEL AERONAUTICS, INC.

By: Paul Madison

Richard S. Becker
James S. Finerfrock
Paul G. Madison

Its Attorneys

Becker & Madison, Chartered
1915 Eye Street, Northwest
Eighth Floor
Washington, DC 20006
(202) 833-4422

Date: May 28, 1993

<u>Exhibit 1</u>

ACADEMY OF MODEL AERONAUTICS TECHNICAL REPORT

"EXPERIMENTAL EVALUATION OF 72 MHZ LAND MOBILE OPERATION ON RADIO CONTROL MODEL AIRCRAFT"

By: William Hershberger
George Steiner
Warren Plohr

ACADEMY OF MODEL AERONAUTICS

Technical Report

Experimental Evaluation of 72 MHz Land Mobile Operation on Radio Control Model Aircraft

by: William Hershberger, George Steiner, and Warren Plohr

May 1993

Approved

Executive Director

AMA
SINCE 1936

1810 Samuel Morse Drive Reston, Virginia 22090

Experimental Evaluation of 72 MHz Land Mobile Operation on Radio Control Model Aircraft

by: William Hershberger, George Steiner, & Warren Plohr

flight path, while a Land Mobile transmitter was operated miles away from the airport. The airborne instrumentation monitored and recorded the interference encountered.

EQUIPMENT DESCRIPTION AND PROCEDURE

Activity prior to actual flight tests included equipment fabrication, preliminary testing and calibration.

Land Mobile transmitter: The mobile transmitter was fabricated from a radio control transmitter because of availability and convenience. Conventional R/C modulation was used. For the purpose of these tests, it simulates a commercial Land Mobile transmitter. The R/C transmitter was modified to have a BNC antenna output terminal to feed a 1/4 wave whip antenna. Two plug-in RF modules operating on R/C channel 42, 72.63 MHz, were used. Both were modified to be able to change the RF output frequency by 7½ KHz. The RF module used for offset mobile frequencies on the high side of the R/C channel had a power output into 50 ohms of +20 dBm, 100 mW, and down-modulated FSK deviation of 2.6 KHz. The other module was used for the low side signal had an output of +27 dBm, 500 mW, and up-modulated FSK deviation of 2.6 KHz.

A diagram of the mobile transmitting station is shown in figure 1. The output of the transmitter was fed to a KAY 432D 100 dB step attenuator, then to a 10 dB gain linear amplifier feeding the antenna through a SWR indicator. The attenuator was used to control the RF output to a one watt level. The level was measured by a calibrated IFR Spectrum Analyzer. The calibration was traceable to a secondary standard, a calibrated Millivac Instruments Model MV-828A, s/n 7253, RF Power Meter. The frequency was measured by an Optoelectronics 8007S portable frequency counter that was calibrated against WWV. The 1/4 wave whip antenna was mounted on the roof of a sub-compact automobile. It was tuned to 72 MHz by adjusting antenna length, and monitoring the SWR measurement. An operator controlled the transmitter at the remote site. An RF field strength meter and a frequency scanner was also used at the site to grossly confirm the transmitted signal. The operator maintained two way communication with the flying site using a hand held VHF radio.

R/C model aircraft: A photograph of the aircraft that was used in these tests is shown in figure 2 . It is a typical four control R/C model with a wingspan of five feet, a gross weight of nine pounds, and powered by a 1/3 HP internal combustion engine. The R/C command signals were provided by a system operating on 53.1 MHz, in the six meter ARS band. The receiver-under-test and the airborne instrumentation comprised the payload of about 3/4 pounds. A photograph of the externally mounted payload is shown in figure 3.

R/C equipment-under-test: Three sets of R/C equipment were used for this experimental evaluation of susceptibility to interference. The sets used top-of-the-line dual conversion receivers. The transmitters are FCC Type Accepted. The receivers have been Certified. Both are *listed* as meeting or exceeding the AMA Radio Guidelines for narrow band R/C equipment. *Listed*, means that a prototype receiver and transmitter were tested by a certified independent laboratory, to meet the Guidelines of reference 2. The specific hardware tested was taken from R/C service where it had been successfully used for sport flying.

The three R/C sets were of different manufacture. Two used *frequency shift keying* (FSK) carrier modulation, often called FM in the model world, and one, 100% down-modulated (carrier off) *amplitude modulation* (AM). The control information was coded as *pulse position modulation* (PPM), providing time shared information to each servo. The timing between 300 µsec modulation pulses provides the servo position information. The position of pulses in a frame of information, and the timing between pulses, provides the control position information to as many as seven servos. The decoder in the receiver clocks the pulses to send 1 to 2 ms position information pulses to each servo. Typically, a servo receives position information every 20 ms.

The three R/C transmitters were operated on Channel 42, 72.63 MHz, within the +/- 4 KHz FCC specified information band width. The RF power outputs ranged from 200 to 500 mW. See reference 3 for a more detailed description of R/C systems.

Instrumentation: The decoded servo output signals from the receiver-under-test were fed to two on-board recorders and a telemeter transmitter.

One of the on-board recorders monitored servo position jitter due to interference. The servo jitter counter (SJC) recorded the number of times the decoded servo position pulse width deviated from the encoded pulse. The encoded pulse width was 1.5 ms. A deviation exceeding +/-50 under-test required another person to simulate an R/C pilot. A test conductor at the flying site made the fifth. The test conductor coordinated the interfering signal via VHF radio as required by the test sequence. He recorded the test sequence, the telemetered data, and the post flight on-board recorder data on a pocket voice recorder. The telemeter record was a simple voice description of the test conductor's observations as he listened to the telemeter signal. The magnetic record was later transcribed to hard copy.

Most model aircraft are flown for an individual's enjoyment, not in competition with other pilots. A typical *fun flight* of a powered model starts with a take-off from the runway, followed by a climb to altitude where aerobatics are performed. The altitude is about 400 feet, and the maximum range from the airport, about ¼ mile. The distance the model is flown from the pilot depends on model visibility, not limitations of radio range. A typical flight is about eight to ten minutes in duration, followed by a runway landing.

The flight pattern used for the interference testing was an abbreviated version of a typical *fun flight*. After take-off, the model climbed to an altitude of 400 feet, where it was flown toward the mobile station. The mobile transmitter was turned on as the model came overhead on the outbound path. Data recording began at that time. The model was flown to the ¼ mile point, where a 180 degree turn was made to fly the model back to the airport. The ¼ mile distance was estimated by the pilot. Earlier flights were made, using a ground spotter at the ¼ mile point to *calibrate* the pilot's judgment of distance. When the model was overhead on the return path, the mobile transmitter was turned off. The model then descended to a landing and the airborne counters were recorded and reset for the next flight. The flight duration was typically two minutes in duration.

RESULTS AND DISCUSSION

Data taken on the flight line of the model airport is listed in tables 1A and 1B. A total of fifty valid data entries were made, and are listed as Test No. 1 through 17, and 19 through 51, in table 1A. Table 1B documents telemetered data. Activities away from the flight line, such as equipment preparation and calibration, are documented in the text.

The fifty-one tests are classified as follows:

31 - R/C interference test flights
6 - R/C calibration flights
4 - Telemeter system tests
9 - Signal strength, and other tests
1 - invalid due to procedural error

Signal strength tests: Tests No. 20, 21, 22, and 50 measured the ground level signal strength of the 1 W mobile transmitter at distances of 3/4 to 2½ miles from the flight line. Measurements ranged from -65 to -90 dBm. When the transmitter power was decreased to 100 mW (Test No. 51), the signal strength decreased to -100 dBm at 1½ miles.

Other tests: Tests No. 6, 7, and 8, were interference tests with a type A receiver at ground level, operating on a nonmetallic table. These tests determined that airborne testing should be made with the mobile transmitter located 3/4 or more miles from the flight line. Test No. 5 confirmed that the Land Mobile transmitter had a 1 W output.

Telemeter system tests: Test flights No. 1 through 4 confirmed that the airborne 10 mW telemeter transmitter, operating on 49.845 MHz, did not interfere with the command control R/C system operating on 53.1 MHz, or the 72 MHz receiver-under-test and it's associated instrumentation. The frame rate count recorded on test No. 1 was believed to be caused by a random airborne antenna null. Calibration flights, tests No. 9, 10, 11, 23, 28, and 37, and subsequent undocumented test flights, also confirmed the compatibility of the telemeter system.

R/C calibration flights: R/C calibration flights, tests No. 9, 10, 11, 23, and 37, were made to confirm that the system operated without recording interference, when no interfering signal was present.

R/C interference test flights: The remaining 31 tests listed in table 1A, and 31 of the 35 tests listed in table 1B, document the interference test flights. Appendix A describes the methodology for evaluating the interference potential from the recorded and telemetered flight data. Using the described criteria, each of the 31 interference test flights were evaluated for the level of interference encountered by the receiver-under-test. Table 2, column 6, tabulates this evaluation for the 31 test flights.

The interference evaluation ranged from *none* to *severe,* with *minor* and *moderate* as intermediate assessments. Interference considered as *minor* will cause the aircraft's control surfaces to wiggle, but will not result in an unwanted aircraft maneuver. *Moderate* interference will result in a small, but easily recognized, unwanted aircraft maneuver. The small disturbance will not result in aircraft damage unless the pilot panics. If an aircraft encounters *severe* interference, the probability is that the out-of-control model will either break up in flight or impact the ground.

Table 3 displays the same data tabulated in Table 2, but it is sequentially sorted on column 6 and 1, to better display the results for this discussion. Ten flights had no interference, ten encountered *severe* interference, six were *minor,* and five were evaluated as *moderate*. Half of the test flights encountered significant interference. The level produced would disturb an aircraft's flight path. One third of the flights experienced a level of interference that would have resulted in an out-of-control aircraft. These flights were made with the mobile transmitter located 1 to 2½ miles from the flight line. Table 3 shows that all levels of interference were encountered at each mobile transmitter location.

Table 4 is a different sorting of the flight data and shows that more flights encountered *severe* interference with the mobile transmitter 1½ miles from the flight line. However, note that fewer comparable test flights were made with the mobile transmitter only 1 mile away, where the most severe interference would be expected. Note that with the mobile transmitter at 2½ miles, operating at a frequency offset of 5 KHz, six flights encountered minimal interference.

The fewer number of flights made with the mobile transmitter located at 1 mile, suggests discounting the data from those tests in the next comparison. Table 5 shows that all three R/C test receivers encountered similar levels of interference if the struck out data is ignored. This result is not unexpected since all three receivers have similar intermediate frequency amplifier circuitry. Furthermore, this

A telemetered indication of interference, a *hit* in table 1B, is heard as *a chirp* on the received audio. When a *chirp* is heard, the airborne counters are recording *hits*. The ground observer, watching the flight and listening to the *chirps*, made a voice recorded description of the scene. Table 1B is a brief transcription of those observations. It provides an informative overview of the way R/C aircraft interact with ground based interference.

The severe interference encountered in flight tests No. 13, 35, 38, 47, 48, and 49 were good examples of the expected distribution of *hits* during a flight. Few or none occur when the aircraft is close to the flight line, increasing in number as the model is flown towards the mobile transmitter, steady chirping at extreme range, and a decreasing number of *hits* as the model is flown back to the flight line. On the other hand, the severe interference encountered during flights No. 30, 41, 42, and 43, was a result of *hits* during the flight towards the mobile transmitter, and few to none on the return path.

The flights with moderate interference, No. 14, 19, 25, 26, and 39, recorded *hits* at unexpected locations. Often there were no chirps at extreme range but some were heard when the aircraft was close to the flying field. Flights with minor interference are even more unpredictable.

This unpredictable non-linear response is due to the tenuous RF link between the R/C transmitter and the airborne receiver. The antenna on the hand held transmitter has less than zero dB gain and a varying antenna pattern as the pilot moves around on the tarmac. Pilots often use the most unfavorable transmitting antenna position. The most comfortable pilot flying position is when the transmitting antenna is pointing at the aircraft, exactly where there is a transmitting antenna null. The trailing wire antenna in the aircraft has even a lower gain, and a varying antenna pattern as the model maneuvers. Maneuvering of the aircraft introduces almost continuous polarization misalignment. Such misalignment can produce as much as a 12 to 18 dB change in signal level.

The RF link between an R/C transmitter and an airborne receiver has been explored experimentally. These tests verified that a receiver must operate over a wide range of signal levels. The unpublished tests indicate that on a normal flight, without the presence of interference, the received signal level often momentarily drops to the receiver's threshold of control, enabling an interfering signal.

With this understanding, it is easy to see that an R/C receiver can be momentarily captured by a weak interfering signal. Once the null is gone, the R/C transmitter takes over again. However, if the interfering signal is strong, the control dropout time is longer, and the aircraft responds.

REFERENCES

1. **COMMENTS OF THE ACADEMY OF MODEL AERONAUTICS**, in the matter of PR Docket 92-235, submitted to the FCC March 10, 1993

2. Academy of Model Aeronautics Membership Manual, 1993. p 15

3. Handbook for the Radio Amateur, an ARRL Publication